



LUNAR MARKET STUDY

Summary pages only

**Conducted in Spring 2018 for a private customer
in collaboration with Finsophy PBC**





SUMMARY

The commercial Space industry is at an historic moment. Currently worth \$339B per year, the industry has experienced unprecedented developments during the past decade and is on a path to becoming a \$2.7T industry by 2045 ([BOAML](#)):

- Launch technology is becoming cheaper, reusable and more reliable – slowly but steadily breaking down the cost barriers of access to Earth orbit, the Moon and beyond
- Indications of abundance of resources (water, rare earth metals and other inorganic materials) have been discovered on the Moon, Near Earth Asteroids and Mars
- 100s of private Space companies have been established and capitalized around the world
- Public and private investment capital into Space companies and start-ups is increasing
- Legal framework breakthroughs and impetus, led primarily by the US and Luxembourg, and as of recently, Japan, have laid the foundation for an emerging free-market beyond-Earth orbit economy

The Moon is gearing up to become the next economic frontier. Our research, analysis and estimations indicate a potential Lunar total addressable market (TAM) worth **\$13.4B (baseline scenario; \$25.9B optimistic, \$5.0B pessimistic)** between 2020-2030 in the form of payloads via rovers, landers and orbiters, data sales, and sponsorships. Our findings are underpinned by >100 public references, including and not limited to:

- Space agency budgets
- NASA & ESA RFIs and solicitations
- Dozens of NewSpace startups and established businesses and their plans as pertaining to Lunar operations and development
- Industry and academic findings on Lunar resources and prospecting, Strategic Knowledge Gaps (SKGs), and In-Situ Resource Utilization (ISRU)
- Codified university interest in Lunar science and exploration
- Mining industry sentiment, exploration budgets and financial reports
- Economic viability analysis of Lunar mining
- Non-Space company sponsorship budgets and terrestrial advertisement norms

ADDITIONAL KEY INSIGHTS

- Nominal total global Space agency Lunar exploration and development budgets estimated at \$1.9B/year by 2025, increasing to \$4.5B/year by 2030
- At least 24 NewSpace companies developing technology and/or business plans directly applicable to Lunar operations and economic development, in addition to 9 major competitors in the deployment of Lunar rovers and landers
- Terrestrial oil & gas and mining industries insights:
 - Mining industry executives do not feel optimistic on the terrestrial mining industry's growth potential; market conditions may be appropriate for beginning to morph their perspective, and potentially appetite for investment, on extraterrestrial mining.
 - Most executives recognize that R&D and early exploration is important
 - Most executives feel comfortable with new mining technology and capabilities
 - On average, they spend ~3-4% of their revenues in exploration and ~15-25% in CapEx for constructing new mines and oil rigs
 - There are 3 oil companies and 1 metals mining company capable of affording the large exploration and CapEx costs associated with Lunar water mining in the late 2020s. We estimate that terrestrial resources companies could invest up to \$1B for exploration and securing tenure (assuming market demand for Lunar water materializes and regulations are in place for the commercialization of Lunar water).

When is the Lunar market inflection point? We anticipate the following required factors towards realizing a Lunar market inflection point:

- Reliable launch costs at \$1,000 / kg (or less) to LEO
- Reduction of transport costs, at scale/volume, to the Moon's surface to <<\$1M per kg
- Lunar surface operations technology (landers, rovers, Lunar night survival, ISRU, navigation, communications, basic prospecting) maturation to TRL-7
- SKG (science and engineering) reduction:
 - More data on polar vs. distributed surface water deposits
 - Extractability of water from regolith
 - Extractability of water from Lunar ice
 - Biological factors (regolith & Lunar dust, radiation, reduced gravity)
 - Shielding technologies (radiation, micro-meteorites)
 - Closed-loop life support systems
- A robust and enabling regulatory framework

Our study assumed that all aforementioned conditions are met and the Lunar market inflection point is achieved in the mid 2020s.

ENABLING FACTORS TOWARDS A CISLUNAR ECONOMY

Government / Space agency budgets are revectoring towards the Moon: NASA has announced codified budget items for Lunar exploration and technology development in the order of \$839M per year starting in 2019. We anticipate that with the transitioning of the ISS towards private operation, an additional up to ~\$1.45B (from the US alone) could be appropriated towards Lunar operations and development. We anticipate a similar trend for Space agencies across the world; there are an additional 11 space agencies, including ESA, that have expressed specific interest in Lunar science and operations. We forecast a nominal total global Space agency Lunar exploration and development budget of **\$1.8B/year by 2025, increasing to \$4.5B/year by 2030.**

The ecosystem of beyond-Earth orbit commercial entities is growing: We have identified at least 24 NewSpace companies developing technology and/or business plans directly applicable to Lunar operations and economic development. This list does not include entities developing rovers and lander capabilities nor US and European established aerospace companies



(Lockheed, Boeing, ULA, SpaceX, Blue Origin, Bigelow, TAS, Airbus, SSTL etc.) currently in support of US and European public-private space programs and Lunar plans. Figure 1 summarizes the emerging NewSpace ecosystem in support of Lunar operations and development.

Figure 1 – Emerging ecosystem of NewSpace companies in the context of Lunar operations, business plans and development.



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Investments in beyond-orbit and/or Lunar companies: Luxembourg's \$227M asteroid mining fund set a new precedent for strategic sovereign investments in the NewSpace industry. Japan recently announced a ~\$1B fund in support of its ambitions for economic development of the Moon and the solar system (<https://asia.nikkei.com/Japan-Update/Japan-to-fuel-space-startups-with-nearly-1bn-funding-pool>). With global interest in the Space industry increasing, we expect more sovereign funds to setup strategic Space funds, including Norway (~\$1T sovereign fund), China (~\$900B) and UAE (~\$828B) (<https://www.swfinstitute.org/sovereign-wealth-fund-rankings/>). The recent BryceTech Space industry report (https://brycetek.com/downloads/Bryce_Start_Up_Space_2018.pdf) also indicated that:

- Total investment (total \$) into Space companies is increasing and so is the absolute number of individual investing entities
- Furthermore, investments in non-US companies is also on the rise

Lastly, the Google Lunar XPrize (GLXP) recently announced that it is being reenacted and seeking a new major financial sponsor.

Technology enablers in support of the emerging Lunar market: Key technology enablers towards unlocking the proliferation of Lunar operations and development include, and not limited to:

- reusable launch capabilities, spearheaded by SpaceX
- increased long-range communications bandwidth via laser communications
- development and manufacturability of lower mass and more efficient solar PVs
- terrestrial and Space-based 3D printing
- compactization and commoditization of low Size, Weight & Power (SWaP) space-qualified electronics and processors, spearheaded by the proliferation of nano and cube-sats the past 10 years
- development and demonstration of high efficiency in-Space electric propulsion systems

The Moon as a stepping stone to expanding humanity's econosphere: *"Our vision is millions of people living and working in space"* – Jeff Bezos, Founder & CEO, Amazon and Founder, Blue Origin. Jeff Bezos is not the only multi-billionaire with eyes set on the economic development of Space. Sixteen (16) of the world's richest 500 people have Space investments and are advocates of the economic development and human settlement of the solar system (<https://www.bloomberg.com/news/articles/2017-08-21/outer-space-obsession-moguls-worth-513-billion-join-the-race>). The Moon and its natural resources (water, inorganics, sunlight, vacuum, low-gravity well) provide tremendous long-term economic potential in the context of an interplanetary economy and multi-location (Earth, Earth orbit, Moon, Mars, asteroids) trade ecosystem: <http://spaceeconomy.spacevault.world/moonvsmars/>

Reduction in transportation costs: SpaceX's inaugural Falcon 9 Heavy launch in early 2018 codified the industry's ability to approach \$1,000 / kg of payload to Low Earth Orbit (LEO). With the continual maturation of reusable rocket technology, commoditization of LEO transportation, and inception of in-Space refueling, launch costs to LEO and beyond are expected to keep decreasing.